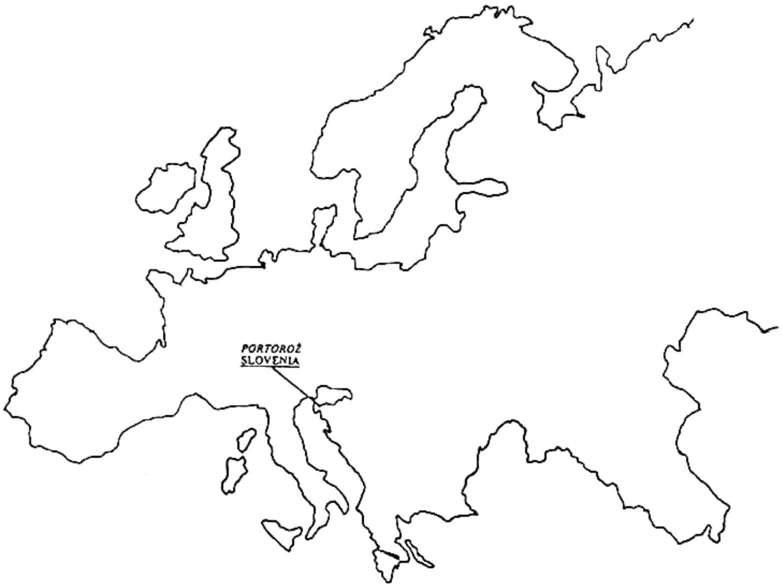
W O R K S H O P

ENGINEERING IN KARST



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During the IMWA 1996 Workshop, fourteen national and international colleagues presented their experience about engineering and mining in karstic regions. The papers presented were not published in a proceedings volume, but handed out to the delegates as paper copies.

This PDF is one of those documents provided to the delegates.

All other papers can be downloaded from www.IMWA.info

Introduction

The significant part of Slovenia represents a Karst with its own hydrogeological and morphological characteristics. the purpose of this article is to discuss the hydrogeological characteristics of karst regions from the water supply and water quality protection point of view.

The Slovenian Adriatic coast and the karstic hinterland named Primorski kras, represents from a water resources management and ecology one in itself closed system, which is, because of its geopolitical position, one of the most noteworthy parts of Slovenia.

Because of the karstic nature the lack of sufficient water represents one of the main obstacles for the development of this region being the only door to the sea of supreme importance for the whole country.

By developing a short and long term waterresources management strategy for this region, some relevant question should be answered and solved which are:

- Are the existent water resources of the region short and long term sufficient to support the economic and cultural growth of the region?
- What should be done to protect the quality and quantity of the existent water resources of the region?
- Is the import of the water from other neighboring water sheds, while its own water resources are not properly protected and used, the economically and ecologically sustainable solution and if, why and when.

In this article we are trying to answer the indicated questions with the purpose to provoke professional discussion as a contribution and support for the decision makers, which are responsible for water resources management on the regional an the whole country level.

CAPACITIES OF PRIMORSKI KRAS WATERRESOURCES REGARDING THE WATER SUPPLY AND PROTECTION

In spite of relatively high average precipitation over 1200 mm/year in the whole region there is not much water directly available (because of rapid infiltration).

The greatest outflow takes place underground. Only a small part perhaps about 10% of the whole participation occurs in the rivers Rižana, N. Reka, Dragonja and some karstic springs.

The underground streams are difficult to be allocated and exploited because of possible changes of flow patterns and discharge fluctuations. Because of the depth of some hundred meters the energy costs for pumpage may also be very high.

Until now in spite of extensive research done in recent 50 years, two underground streams have been successfully found and exploited (Klariči 250 l/s Hp ≅ 600 m, Sečovlje 50 l/s Hp ≅ 100 m).

Except of these two underground streams, the only important karst spring is that of the river Rižana (of about 240 l/s capacity). They are presently the main drinking water sources which are already fully used for the drinking water supply of the region.

The total available capacity cca 490 l/s of the drinking water sources now exploited are only temporarily supplemented by 60 l/s from the neighboring water supply system of Croatia.

Total water resources capacity is today of about 550 l/s.

According to urban and economical planning of the region in next 30 years an increase in water consumption in expected to about 1000 l/s.

It means that additionally about 600 l/s of drinking water is needed to ensure the water supply for the planned development of the region.

To cover the needs of the future water supply two main possibilities exists:
To import the water from the spring (named Malni) of an karstic underground stream of a neighboring watershed of the river Ljubljanica or, to employ the surface water of the river N. Reka in the center of the Primorski karst region in question.

Both watercourses have sufficient water to cover the needs.

Except of the economical evaluation, the quality, safety of water supply and ecological impacts of extracting the water out of both watersources should play a decisive roll.

THE QUALITY AND RISK ASSESSMENT OF THE POSSIBLE ALTERNATIVE WATERSOURCES N. REKA AND MALNI

According to the extensive analyses of the chemical and bacteriological quality of the spring Malni (which is supplied by the underground stream formed of two main contributors Cerkniško jezero (lake) and the river Pivka) is to some degree of better quality as N. Reka which is a classical surface water.

But as it is seen from the water quality data (see the attached tables 1 and 2) both sources belong to A category as a row sources of drinking water according to the German drinking water quality standards (table 3).

If both waters, as a result of their quality, are amenable to the same classical technology of drinking water treatment, the major question, except of economics, is the safety of both watersources against accidental pollution.

By judging the safety against accidental pollution the following criteria could be applied:

	Criteria	N. Reka surface water	Spring of Malni Karstic underground stream
1	The existent quality of rough drinking water source	-	+
2	The possibilities to control and prevent the permanent pollution	+	+
3	The possibility quickly to determine the place and cause of pollution	+	-
4	The possible duration of pollution of water	+	-
5	The self purification capacity of the raw water in question before reaching the extraction point	-	+
6	The size of the water catchment area (bigger (-), smaller (+)	+	-

7	The morphologic and pedologic properties of the catchment area	0	0
8	The population of the cathchment area	+	-
9	The traffic density of the catchment	-	-
10	The degree of industrialization	-	-
11	The hot spots of accidental pollution	-	-
12	The possibilities to immediately counter act to prevent the negative consequences of accidental pollution on drinking water quality and quantity	+	-
13	Ecological disadvantages - advantages of extracting raw water	+	-
	Σ (+) Σ (-)	7(+) 6(-)	3(+) 10(-)
	ΣΣ	13	13

In the following we will try shortly to explain the evaluations in the above table.

By assessing both drinking water sources according to evaluated properties in the table above, the advantages of surface waters of N. Reka against the spring Malni of underground karstic stream (54% positive points of total) against (23,0% positive points of total) could be concluded.

The existing raw water quality of the spring of the karstic underground stream Malni should be, in spite of its underground route, treated as an surface water.

Its better quality from bacteriological, physical and chemical point of view in dry periods is because of longer water detention time underground, when compared with surface river water in dry whether flow (1). For example for Malni spring the average underground flow velocity measured was of order of 5-6 cm/s and the underground detention time of about 20 hours. (Acta Carsologica VIII. 1978, Slovenska akademija znanosti in umetnosti; Sledenje v zaledju Rižane, 1988, HMZ; Rižana v = 0,97 m/s).

Detention time and flow velocity are of the order of the plain settling tanks used in drinking water treatment.

On the other hand, the flow velocities of surface river water of N. Reka are of the order 1-2 m/s and the flow time between the main polluter the city of Ilirska Bistrica and the possible extraction point by Cerkvenikov Mlin (about 17,0 km distance) takes only about 3 hours.

But in the times of heavy rainfall or intensive snow melting the quality of karstic underground streams approaches the quality of river surface waters. In many cases the load of suspended solids is even higher.

Generally this are the reasons both waters need similar or even the same technology of treatment.

By strict control (it is needed in both cases) the technical means to prevent the permanent pollution are nearly the same (2). All the polluters which could have detrimental effect on the recipients water quality should be eliminated or treated and put under control.

Because of mainly unknown underground passages of the pollutants no selfpurification capacity of underground streams should be trusted.

Also the possibility to quickly find the place and the cause of the pollution of karstic underground streams is as a rule much lower than by river surface water (3).

In the case of accidental (or permanent) surface river water pollution the place and cause of pollution, by tracing the pollution upstream, is quickly possible to establish (5).

Because of rapid river surface water flow (without underground storage reservoirs) the pollution quickly passes the waterextraction point. The sanitation of the river bed itself, if needed, to some extent is possible too. By underground streams neither is the case. As a result the duration of pollution is much longer (4).

As already mentioned, the selfpurification of the underground streams is higher as in unimpounded surface river waters. (5)

The bigger size of the catchment areas (by approximately the same density and hydrogeological conditions) represents greater probability for accidental pollution to occur. (6)

The same is true for the population density and the morphologic and pedologic properties of the catchment area and the traffic network density and frequentation (7, 8, 9).

The higher the industrialization the higher is the danger of accidental pollution (10).

In this case on both catchment areas some hot spots (11) exists of possible accidental pollution: the existent industry is present in both areas. On the catchment area of karst underground stream of the spring Malni the industry is more numerous and in many places (Cerknica, Lož, Bloška planota, Postojna) while by N. Reka the industry is concentrated only in the city of Ilirska Bistrica. But in later area the river water is perhaps more exposed to traffic accidental pollution (because on some stretches the main road closely follows the river bed) in spite of the fact that the very frequented high way is crossing the underground streams of the Malni spring. By extracting the raw drinking water from the river it is (in contrary to the underground stream of Malni) possible to control the quality by the construction of water reservoirs of several days drinking water consumption capacity (12).

The same is otherwise, but not in these case, generally possible also using the underground water streams, but the necessary reservoirs (because of longer duration of pollution) have to be of bigger size.

The use of surface river water of N. Reka has in this case also, as it will be explained later, except economic, also ecological advantages (13).

Comparing the feasibility of both drinking water sources under consideration, the construction of the high quality municipal WWT which is one of the preconditions to use N. Reka river for drinking water supply. But it is in any case necessary to improve the over all ecological quality of the river to enable it for trout fishery, other water sports etc.

Because of more or less permeable cover of karstic wells and underground streams the protection measures applied do not differ from rivers surface water protection. Because the ways of underground karstic streams are mainly insufficiently known and because of that more exposed to uncontrolled pollution, the protective measures should even be stronger.

The available and the necessary protection technique for both waters discussed is practically the same:

- The construction of efficient WWTP with desinfection of effluent specially where there is a short contact time between effluent discharge and extraction for water supply is necessary and unavoidable.

- The construction of sewer systems with the higher (as usually) quality control of rain water overflows.

- The control and prevention of uncontrolled spillage of contaminants directly or indirectly into watercourses with special care about uncontrolled landfills etc.

- The control of use of fertilizers and pesticides in agriculture and forestry.

THE WATER RESOURCES MANAGEMENT IN WATER SCARES KARST REGIONS NEEDS INTEGRATED APPROACH TAKING INTO ACCOUNT WATER PROTECTION AND USE

In Karstic regions, like Primorski kras and Slovenian coast, the water is a limiting factor for the economic and cultural development, for the region as well as for the whole country.

An integrated, ecologically and economically sustainable water resources management is needed based on the following principles:

- Water quality and quantity protection of the existent water resources of the watershed of Primorski kras and slovenian coast which forms an ecological entity should be the precondition for all kinds of water uses needed in the region.

- Following this line the positive synergetic effects of water quality protection and river low water augmentation of N. Reka should be used as a support to rational and ecologically reasonable water resources management of the region.

- The interect reuse (as in the case of using N. Reka for water supply) and direct reuse of water is an undismissable measure for ecologically an economically efficient water resources management.

- It is necessary to introduce also all possible kinds of direct water reuse to reduce the total water demand.

The effluent of WWTP should be used for:
- agricultural irrigation,
- irrigations of sporting fields,
- urban green areas,
- street flushing,
- cooling water for industry etc.

- An thorough analysis should be made before deciding to import water from other catchment areas, thus changing the natural water balance and ecological conditions in the otherweise affected neighborring watershed.

- A careful analysis about the quality and quantity questions where choosing new water sources for drinking water supply is nedeed.

  By ensuring adequate and safe raw water protection measures and drinking water purification techniques the already engaged karst underground streams of Rižana, Sečovlje and Klariči and surface river water of N. Reka could guarantee the necessary quality, quantity and safety of drinking water supply.

  That is the reason that for the forseable future no costly and ecologically determental import of water from other water sheds is needed when an integrated water resources management is applied.

- By the costly import of water from watershed of Ljubljanica the flow of the highly ecologically an landscape valuable river of Unec would be depleted. On the contrary by using N. Reka for watersupply the ecologically pozitive augmentation of this rivers low water flow (by using 8x10 m^3 water storage of the existent two reservoirs) is while the river Unec remain unaffected.

- Only if the karst underground streams is possible effectively and controllable to protect (like for example the Wiena Waterworks have done) the karst wells can guarantee the hygienic quality of water.

- In the case of underground stream of Malni in question no such guarantee could be given because the catchment area is urbanized, industrialized and crossed by highways and other frequented communications.


THE PLANNED TRANSPORT PIPE
35 km
Q = 1000 l/s
PROJECTED SKOCJAN CAVE
PROPOSED ALTERNATIVE EXTRACTION OF 1000 ÷ 1500 l/s RIVER WATER
WWTP NOT YET EXISTENT
ILIRSKA BISTRICA
2 WATER RESERVOIRS
EXISTENT
WELL
RIZANA
Qmin = 300 l/s
BRESTOVICA
WELL 250 l/s
38 km
Q = 250 l/s
EXISTENT PIPE
POSTOJNA
CERKNICA
RAKEK
DIVAČA
SEŽANA
TRIESTE
KOPER
IZOLA
MUGGIA
VILLA OPICINA
VIPAVA
PIVKA
PODGRAD

TABELA 2: Rezultati fizikalno kemijskih, bakterioloških analiz in analiz kovin voda ocenjenih po predpisih EEC za pitno vodo

Kraj zajema vzorca: Mlinščica - Malni

Datum	09.03.93	26.05.93	16.06.93		03.08.93	11.08.93		17.11.93
Temperatura vode (st.C)	8	9.6	8.4		10	10		5.4
Barva (mg Pt/l)	0	2 *	1		2 *	3 *		4 *
pH	8.0	8.0	7.9		8.1	7.9		7.7
Elektroprevodnost (nS/cm)	292.0	333.0	313.0		335.0	325.0		167.0
Nasičenost s kisikom %	106.4	102.5	99.5		109.8	106.2		99.6
KPK iz KMnO4 (mgO2/l)	1.4	1.4	1.6		1.9	1.7		2.6 *
Susp. snovi(mg/l)	22.8 *	7.5 *	10.8 *		7.4 *	17.1 *		3.1 *
Suhi ost.filtr.vode(mg/l)	186.0	192.0	208.0		206.0	205.0		208.0
Amonijev ion (mg/l)	0.19 *	0.07 *	0		0.12 *	0.15 *		0.09 *
Nitrat (mg/l)	4.9	5.5	1.2		5.8	6.2		2.4
Nitrit (mg/l)	< 0.01	0.01	0.01		< 0.01	< 0.01		0.01
Sulfati (mg/l)	10.3	7.7	7.2		8.8	7.7		10.3
Silicijev dioksid (mg/l)	1.8	1.7	1.8		1.8	1.8		1.5
Fe (mg/l)	0.01	< 0.01	< 0.01		< 0.01	< 0.01		0.01
Al (mg/l)	0.01	0.01	0.02		0.01	0.01		< 0.01
Mg (mg/l)	8.2	5.2	5.6		6.9	5.2		10.4
Ca (mg/l)	55.1	62.9	61.5		65.8	63.6		58.6
K (mg/l)	0.2	0.3	0.2		0.3	0.3		0.4
Kloridi (mg/l)	2.8	2.8	2		2.5	2.3		1.9
Na (mg/l)	1.3	1.4	1.4		1.4	1.5		1.2
Detergenti, anioakt. (mg TBS/l)	< 0.01	< 0.01	0.01		< 0.01	< 0.01		< 0.01
Mineralna olja (mg/l)	0.03 #	< 0.005	< 0.005			< 0.005		
Koliformne bakt. (skupne MPN/l)	2000 #	2000 #	2000 #		2000 #	2000 #		2000 #
Bakt. fekalnega iz.	0	0	0		0	0		0
Kovine			filtr.	susp.		filtr.	susp.	
Baker (mg/l)			< 0.005	< 0.005		< 0.005	< 0.005	
Cink (mg/l)			< 0.05	< 0.05		< 0.05	< 0.05	
Kadmij (mg/l)			< 0.001	< 0.001		< 0.001	< 0.001	
Krom (mg/l)			< 0.005	< 0.005		< 0.005	< 0.005	
Nikelj (mg/l)			< 0.005	< 0.005		< 0.005	< 0.005	
Svinec (mg/l)			< 0.005	< 0.005		< 0.005	< 0.005	
Hg (mg/l)			< 0.0005	< 0.0005		< 0.0005	< 0.0005	

* - presežena GL (guide level)

\# - presežena MAC vrednost (maximum admissible concentration)

TABEL 2

TABELA 2: Rezultati fizikalno kemijskih, bakterioloških analiz in analiz kovin voda ocenjenih po predpisih EEC za pitno vodo

Kraj zajema vzorca: Notranjska reka - Cerkvenikov mlin

Datum	03.03.93	13.05.93	10.06.93	13.07.93	22.09.93	26.10.93
Temperatura vode (st.C)	2.4	14 *	19 *	15.2 *	13.6 *	9.8
Barva (mg Pt/l)	6 *	6 *	7 *	7 *	5 *	8 *
pH	8.2	8.2	8.1	8.5	8.2	7.9
Elektroprevodnost (nS/cm)	271	313	320	309	342	282
Nasičenost s kisikom %	107.8	106.3	97.7	110.1	103.4	91.1
KPK iz KMnO4 (mgO2/l)	4.3 *	6.1 #	4.2 *	3.2 *	2.3 *	2.4 *
Susp. snovi(mg/l)	4.9 *	5 *		10.2 *	3.2 *	6.5 *
Suhi ost.filtr.vode(mg/l)	172	188	200	214	272	222
Amonijev ion (mg/l)	0.17 *	0.17 *	0.17 *	0.74 #	0.16 *	0.14 *
Nitrat (mg/l)	3.6	2.6	3.1	3.4	4.1	4.8
Nitrit (mg/l)	0.03	0.03	0.03	0.02	0.01	0.02
Sulfati (mg/l)	15.5	15	15.5	15.5	16.5	14.5
Silicijev dioksid (mg/l)	1.4	1.1	4.3	3	2.7	5.4
Fe (mg/l)	0.06 *	0.03	0.02	0.02	0.03	0.02
Al (mg/l)	0.04	0.03	0.01	0.01	0.03	< 0.01
Mg (mg/l)	8.2	5.2	3.9	5.6	4.8	3.5
Ca (mg/l)	45.8	55.1	54.3	61.5	70.1	61.5
K (mg/l)	1.2	1.4	2.1	1.8	1.6	1
Kloridi (mg/l)	7.9	4.8	7.2	5.4	4.2	3.5
Na (mg/l)	4.3	4.9	5.6	4.8	4.2	2.8
Detergenti, anioakt. (mg TBS/l)	0.11	0.02	0.05	0.17	< 0.01	< 0.01
Mineralna olja (mg/l)		0.011 #		0.011 #	0.015 #	0.058 #
Koliformne bakt. (skupne MPN/l)	2000 #	2000 #	2000 #	2000 #	2000 #	80000 #
Bakt. fekalnega iz.	0	0	0	+	0	++
Kovine						
Baker (mg/l)						
Cink (mg/l)						
Kadmij (mg/l)						
Krom (mg/l)						
Nikelj (mg/l)						
Svinec (mg/l)						
Hg (mg/l)						

* - presežena GL (guide level)
# - presežena MAC (maximum admissible concentration)

Kriterij	Enota	Razred A	Razred B
Elektroprevodnost	(μS/cm)	500	1000
Deficit O_2	v.H.	20	40
Barva	mg/l Pt	5	50
Vonj	-	5	50
Skupna teža raztopljenih snovi	mg/l	400	800
Suspendirane anorganske snovi	mg/l	150	200
Anorganske substance (podane skupno raztopljene in suspendirane snovi, če ni drugače omenjeno)			
Amonij	mg/l	0.2	1.5
Arzen	mg/l	0.01	0.03
Barij	mg/l	1.0	1.0
Berilij	mg/l	0.0001	0.0002
Svinec	mg/l	0.03	0.05
Bor	mg/l	1.0	1.0
Kadmij	mg/l	0.005	0.01
Kalcij	mg/l	100	-
Klorid	mg/l	100	200
Krom	mg/l	0.03	0.05
Cianid	mg/l	0.01	0.05
Železo (raztopljen)	mg/l	0.1	1.0
Fluorid	mg/l	1.0	1.0
Kobalt	mg/l	0.05	0.05
Baker	mg/l	0.03	0.05
Magnezij	mg/l	30	-
Mangan (raztopljen)	mg/l	0.05	0.5
Nikelj	mg/l	0.03	0.05
Nitrat	mg/l	25	50
Živo srebro	mg/l	0.0005	0.001
Selen	mg/l	0.01	0.01
Sulfat	mg/l	100	150
Vanadij	mg/l	0.05	0.05
Cink	mg/l	0.5	1.0
Suspendirane organske snovi -v tekoči vodi - v stoječi vodi	 mg/l mg/l	 5 0.5	 25 1.0
Organske substance			
Raztopljeni organski C skupaj	mg/l	4	8
Raztopljeni organski C po flokulaciji in membranski filtraciji	mg/l	2	4
KPK (bikromatna metoda, filtriran)	mg/l	10	20
BPK_5 (filtriran)	mg/l	3	5
Skupinski parametri (filtriranih vzorcev)			
Ogljikovodiki	mg/l	0.05	0.2
Tenzidi	mg/l	0.1	0.3
Policiklični aromati	mg/l	0.001	0.003
Vodohlapni fenoli	mg/l	0.005	0.01
Organsko vezani Cl kot Cl	mg/l	0.05	0.1
Lipofilne organske Cl-spojine kot Cl	mg/l	0.01	0.02
Organoklorovi pesticidi skupaj (in PCB) kot Cl	mg/l	0.002	0.01
Organoklorovi pesticidi posamezno kot Cl	mg/l	0.001	0.005
Sintetični polimeri	mg/l	0.1	0.3

Razred A - voda je primerna za predelavo v pitno vodo ob običajnem čiščenju

Razred B - voda je primerna za predelavo v pitno vodo ob dražjem čiščenju